UNIVERSITY OF ILLINOIS

GRADUATE STUDY AND RESEARCH IN MECHANICAL ENGINEERING

URBANA, ILLINOIS
1948

FOREWORD

The Department of Mechanical Engineering offers advanced study and professional training in the general fields of power, design, and production.

Graduate study presupposes maturity of outlook. Progress is judged not only by the accumulation of units of credit but also by evidence of intellectual growth and achievement. The following criteria may be considered as evidence of maturity:

a. Display of initiative in outlining work, examining literature, developing equipment, obtaining data, and preparing reports.

b. Ability to do independent work and to present orally and in written form the results of investigations.

This booklet contains extracts from the *Graduate College Announcement* and certain other information pertaining to graduate study, scholarships, fellowships, teaching assistantships, and research graduate assistantships available to mechanical engineering graduates who wish to pursue graduate study and research. Information is included also on graduate courses offered by the Department of Mechanical Engineering.

The courses now offered in mechanical engineering cover the subject matter for which there is the greatest demand and for which staff members and facilities are at present available. Although the courses are planned to develop the competence of the student in a chosen subdivision of mechanical engineering, he has considerable freedom of choice. With the approval of his adviser, he may take courses in more than one field of mechanical engineering, or in other branches of engineering, mathematics, or the sciences.

Additional information may be obtained from the Head of the Department of Mechanical Engineering, Mechanical Engineering Building, Urbana, Illinois. For a complete statement of the regulations of the Graduate College, students should consult the *Graduate College Announcement,* copies of which may be obtained from the Graduate College, 109 Administration Building, Urbana.

GRADUATE FACULTY IN MECHANICAL ENGINEERING

Norman Alwyn Parker, M.S., M.E.
Professor of Mechanical Engineering and Head of the Department
(Adviser to Graduate Students)

Edward Louis Broghamer, M.S., M.E.
Associate Professor of Mechanical Engineering

William Nelson Espy, M.S.
Professor of Mechanical Engineering

Julian Robert Fellows, M.S.
Professor of Mechanical Engineering

Clarence Walter Ham, B.M.E., M.E.
Professor of Machine Design

John Adams Henry, M.S.
Associate Professor of Mechanical Engineering

Albert Eby Hershey, Ph.D.
Research Professor of Mechanical Engineering (on leave of absence)

William Lavaldin Hull, M.M.E., M.E., M.S.
Associate Professor of Mechanical Engineering

Seichi Konzo, M.S.
Professor of Mechanical Engineering

Everett Laitala, M.S., M.E.
Associate Professor of Mechanical Engineering

Reinhold Fridtjof Larson, Ph.D.
Professor of Mechanical Engineering

Ross J. Martin, M.S.
Assistant Professor of Mechanical Engineering

Leo Charles Pigage, M.S., M.M.E.
Associate Professor of Mechanical Engineering
in Labor and Industrial Relations and Extension

David Gerald Ryan, M.S., M.E.
Professor of Mechanical Engineering

Herman John Schrader, M.S.
Research Professor of Theoretical and Applied Mechanics
(cooperating in Mechanical Engineering Department)

William H. Severns, M.S.
Professor of Mechanical Engineering (inactive status)

Kenneth James Trigger, M.S., M.E.
Professor of Mechanical Engineering

GRADUATE COLLEGE REQUIREMENTS

Admission

Admission to the Graduate College may be granted to graduates of institutions whose requirements for the bachelor's degree in mechanical engineering are substantially equivalent to those of the University of Illinois and to applicants from other institutions approved by the Executive Faculty.

Admission to graduate courses may be granted only to those who have had the requisite undergraduate work for those courses. Students whose preparation is considered inadequate may be required to take without credit certain undergraduate courses. A student of mature age who satisfies the Dean of the Graduate College and the Department of Mechanical Engineering of his ability to pursue graduate work in a given field may be enrolled in certain graduate courses, without reference to a degree, and with the approval of the department and Graduate College be permitted to carry on desired work under the direction of the department.

Application blanks for admission may be obtained from the Director of Admissions and Records of the University, 100a Administration Building. Each applicant must submit with his application for admission an official transcript of his college record.

Basis of Credit

Credit for graduate work is counted in units. A unit course requires approximately ten hours of time each week through one semester, irrespective of the distribution of that time in class work, laboratory or field work, or private study. Four such courses constitute a student's normal program for one semester.

The Degree of Master of Science

Amount of Work Required. — Candidates for the degree of Master of Science in Mechanical Engineering are required to do at least one full year's work in residence, or its equivalent, including a thesis. The requirement of a thesis may be waived in exceptional cases. Four to five units constitute a normal semester program for the master's degree. A minimum of eight units must be completed for the degree when a thesis is included. A minimum of nine units is required if a thesis is not included. Only students with high scholastic standing are permitted to complete their graduate studies with these minimum programs.

Majors and Minors. — A candidate for a master's degree may do all his work in one subject, or he may select a major and one minor, or a major and two minors. A major or minor denotes the field of knowledge of a department, or such part thereof as constitutes a separate and independent division of that field. For a master's degree a major is at least one-half of the work, or a minimum of four units, for one year. Less than one unit may not be counted as satisfying the requirements of a minor without the approval of the department.

Masters' Theses. — Each candidate for a master's degree, with the exception noted above, is required to present two copies of a thesis on some subject approved by the professor in charge of his major work. The thesis will ordinarily demand from one to two units of work.

The Degree of Doctor of Philosophy

The degree of Doctor of Philosophy in Engineering is offered in certain fields of academic work of a high scholastic type in engineering science for students who wish to prepare themselves as experts, investigators, and teachers. The general requirements for this degree, as to preliminary education, linguistic attainments, etc., are given in the *Graduate College Announcement.*

A student in mechanical engineering who desires to become a candidate for the degree of Doctor of Philosophy in Engineering is required to pursue a major subject in the department. He is also required to choose one minor subject, or he may choose two. If one minor only is chosen it must be taken in a department of study other than that of the major, and credit for it may be earned by work representing not less than four units, or one-sixth of the total residence required for the doctorate. If two minors are chosen, one must be a subject closely related to the major. With the approval of the adviser and the Dean it may be a division of the major field of study. The other minor (not less than two units) must, in that case, be taken in a department of study other than that of the major.

BUILDINGS AND EQUIPMENT

The teaching and research activities of the Department of Mechanical Engineering are at present conducted largely in the following buildings: Mechanical Engineering Laboratory, Production Laboratories, and Transportation Building. It is expected that some facilities in the new Mechanical Engineering Building will become available by December, 1948.

Mechanical Engineering Laboratory

This laboratory houses the steam power, internal combustion engine, fuel-testing, heating, ventilating, air conditioning, and refrigeration equipment used in the testing and experimental work required in the mechanical engineering curriculum.

Production Laboratories

In these buildings are the pattern design room, foundry laboratory, machine tool laboratory, welding laboratory, and heat treatment of metals laboratory. Some of these laboratories will be moved to the new Mechanical Engineering Building.

Transportation Building

The Department of Mechanical Engineering has at its disposal class rooms, drafting rooms, and model equipment in the Transportation Building sufficient to accommodate the students in mechanical engineering design.

Other Facilities

Graduate students in mechanical engineering frequently elect courses which make use of the laboratories of the Department of Theoretical and Applied Mechanics which are located in Talbot Laboratory. This laboratory is well equipped with facilities for research work in subjects closely related to the work in machine design and fluid flow.

New Laboratories

The new Mechanical Engineering Building, under construction in 1948, will house many laboratories of the department. The new laboratories include: internal combustion engine and turbine laboratory, thermodynamics laboratory, instrumentation and controls laboratory, fuels and lubricants laboratory, heat transfer and chemistry laboratory, motion and time study laboratory, machine design laboratory, machine tool laboratory, welding laboratory, heat treatment of metals laboratory, metal cutting laboratory, and gauge calibration laboratory.

Engineering Library

The Engineering Library provides unusual facilities for students pursuing advanced work. This library, located in Engineering Hall, contains 52,000 volumes, including books, bound volumes of magazines, and publications of engineering societies. More than 550 technical magazines and publications of engineering societies are currently received. It includes an excellent collection of general technical dictionaries in several foreign languages with definitions in English, as well as similar dictionaries in special fields of engineering.

SCHOLARSHIPS, FELLOWSHIPS, AND ASSISTANTSHIPS

Scholarships and Fellowships

A number of scholarships and fellowships have been established by the Trustees of the University open to candidates who are not more than thirty years of age at the time when the appointment is to be made. To first-year graduate students of ability and promise there are open a number of scholarships carrying stipends of $700 and exemption from the payment of the usual tuition fee. Fellowships open to second-year and third-year graduate students carry stipends of $850 and $1,000, respectively, and exemption from tuition. To be eligible for a $1,000 fellowship, an applicant must have completed the language requirements and must have passed the preliminary examination not later than four weeks following the effective date of the award.

Candidates for these scholarships and fellowships must be graduates of the University of Illinois, or of colleges or universities having equivalent requirements for bachelors' degrees.

Application must be made on forms obtainable from the Dean of the Graduate College. These forms must reach the Dean of the Graduate College not later than February 15 of the academic year preceding that for which the fellowship is desired. Applications received later than February 15 will not be considered until after April 15, the date when appointees from the first list of applications must accept or refuse their appointments.

Nominations to fellowships are made on the grounds of worthiness of character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself.

Teaching Assistantships

A number of teaching assistantships on one-half time or one-quarter time basis are available to graduate students in mechanical engineering. The stipend is $1,200 for a half-time assistant and $600 for a quarter-time assistant, for a school year of two semesters, and exemption from tuition, laboratory, library, and supply fees. A half-time assistant can carry up to three units of graduate work each semester. It is usually possible to assign an assistant to the teaching of a course in the field of his special interest. Inquiries concerning these positions should be directed to the Head of the Department of Mechanical Engineering.

Research Graduate Assistantships in the Engineering Experiment Station

The Engineering Experiment Station is devoted to the study of problems of special importance to engineering, and to the stimulation and elevation of engineering education. By undertaking a line of graduate study in close association with some one of the projects carried on in the Station, the student may come into contact with aspects of his specialty which he would rarely touch in a purely academic study. The Experiment Station makes available apparatus, equipment, and the services of mechanicians, which may materially facilitate the progress of investigations.

Research graduate assistantships with a stipend of $1,200 for a school year of two semesters, and exemption from the payment of the usual tuition fee, are open to graduates of approved technical schools and universities. Applicants to whom these graduate assistantships are awarded agree to hold them for two school years, devoting one-half of their time to the work of the Engineering Experiment Station. A research graduate assistant can carry up to three units of graduate work each semester. At the end of this period, if all requirements of the Graduate College have been met, the degree of Master of Science will be conferred.

A number of research graduate assistantships in mechanical engineering are available. They include assistantships established by the University and others provided by cooperative research agreement with State and Federal agencies, technical societies, and engineering associations. Fields of research which are now active include thermodynamics, heating, ventilating, air conditioning, refrigeration, steam power, internal-combustion engines, fuel testing, flow of fluids, heat transfer, gas turbines, jet propulsion, machine design, power plant design, product design, heat treatment of metals, metal processing, time and motion study, and production methods. It is usually possible to assign a research graduate assistant to a project in the field of his special interest. Often the research in which he is engaged will form the basis of his thesis, but his thesis is not restricted to this field.

Applications for research graduate assistantships should be made to the Director of the Engineering Experiment Station not later than March 1.

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ADDENDUM TO GRADUATE BULLETIN
DEPARTMENT OF MECHANICAL ENGINEERING

The following courses have been added to the curriculum in the Department of Mechanical Engineering.

M.E. 305 - Thermodynamics of High Velocity Flow. The thermodynamics of gases during high-velocity flow within enclosed channels using Mach number as the fundamental variable. Analyses of the basic flow equations, effects of friction and plane shock theory. Application to thermodynamic cycles involving nozzles, diffusers, compressors, combustion and turbines. Prerequisite: M.E. 206 or consent of instructor. Mr. Zubko

M.E. 404 - Gas Dynamics. Properties of compressible fluids, subsonic and supersonic flow, steady and non-steady motion, one-, two-, and three-dimensional problems, shock waves, special problems in connection with combustion engines. I; 1 unit. Prerequisite: Differential equations, thermodynamics, and fluid mechanics. Mr. Korst.

M.E. 432 - Theory of Rotary Compressors. Thermodynamical and mechanical fundamentals, compression with and without cooling, classification of compressors, similarit considerations and characteristics, principles of and computations for radial compressors, improvement in performance of integrating parts; axial flow compressors; lattice and airfoil theory; change in operating conditions of turbocompressors; regulation; rot positive blowers. II; 1 unit. Prerequisite: Undergraduate courses in thermodynamics and fluid mechanic (Mechanical Engineering 205 and 206; Theoretical and Applied Mechanics 232 or Aeronautical Engineering 211 and 212). Mr. Korst.

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Applications for research graduate assistantships should be made to the Director of the Engineering Experiment Station not later than March 1.

FEES

Tuition Fee

Residents of Illinois, except those holding scholarships, fellowships, and teaching and research assistantships, pay each semester a tuition fee of.....$40.00

Nonresidents of Illinois, except those holding scholarships, fellowships, and teaching and research assistantships, pay each semester a tuition fee of..... 80.00

Hospital and Medical Service Fee

All students registering for resident work, except those who are on University appointment other than fellows and scholars or on appointment in allied surveys and laboratories on the Urbana campus, and those who are registered for not more than one unit of graduate work, pay each semester a hospital and medical service fee of..... 5.00

Laboratory, Library, and Supply Fee

Students taking more than two units of instruction pay each semester a laboratory, library, and supply fee of..... 8.00

Illini Union Service Charge

All students registering for resident work, except those who are members of the University staff and others who are registered for not more than one unit of graduate work, are assessed each semester an Illini Union service charge of..... 5.00

COURSES IN MECHANICAL ENGINEERING

The graduate courses described herein will be offered subject to the requirements of minimum registration, availability of staff, and plant limitations.

The prerequisite for graduate work in mechanical engineering is the equivalent of the undergraduate courses required for the degree of Bachelor of Science in Mechanical Engineering. Courses numbered in the 300 group are those open to advanced undergraduates and graduate students, and those in the 400 group are for graduate students only. In registering for a course with variable credit, as ½ to 1½ units, each student puts on his study-list the number of units for which he intends to take the course. Courses numbered in the 300 group have variable credits of ½ to ¾ unit; the ½ unit represents credit for work corresponding to advanced undergraduate study; the additional ¼ unit requires a term paper.

Notes for Laboratory Investigations

The following general notes apply to all graduate courses ending in 8 and 9 and designated as "Laboratory Investigations."

Selection of Topic. — If the student has a specific problem that can be handled with existing or contemplated facilities and funds, such problems will be given preference. If the student has no specific problem to suggest, he may be furnished a list of projects from which a choice can be made, subject always to availability of funds, equipment, and staff.

Procedure. — Preliminary conferences should be arranged with the staff member in charge, and a working program outlined. This outline should include: (a) history of project; (b) importance of subject and its place in the field; (c) proposed or alternate approaches to the solution; and (d) suggested references for bibliographical survey with instructions as to type of abstracts desired and method of indexing same.

Projects. — In general, projects which satisfy any or all of the following requirements should be considered: (a) studies of methods of testing, or development of instrumentation; (b) exploratory research of unknown or controversial items; (c) investigations of physical constants; and (d) investigations which may border on routine or repetitive work, but which may acquaint the student with a number of fundamental measurements and analyses. Although the courses are entitled "Laboratory Investigations," part or all of the work may be of analytical nature.

Maximum Credits. — Except under unusual circumstances the maximum number of credits which will be permitted in any course

ending in 8 or 9 will be three units towards the requirements for a master's degree. An additional four units of credit will be permitted for candidates working towards a doctor's degree. In most cases the research work conducted in these laboratory investigations can be reported in the thesis submitted for fulfillment of the requirements for each degree.

Courses for Graduates and Advanced Undergraduates

301. Engineering Thermodynamics. — ½ to ¾ unit; three one-hour periods a week; first semester. *Prerequisite:* Mechanical Engineering 205 and 206. Professor Espy.

Application of principles of thermodynamics to engineering processes with special attention to steady flow of a compressible medium in insulated or non-insulated ducts, availability of thermal energy, heat and power from combustion, methods of formulation and correlation of properties of a pure substance, and effect of equilibrium on the analysis of internal combustion engines and cycles.

Text: *Thermodynamics,* Keenan.

303. Fuels and Combustion. — ½ to ¾ unit; two two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Inorganic Chemistry or Chemistry of Metallic Elements. Professor Fellows.

Natural and manufactured fuels and their constituents, combustion theory and techniques, smoke abatement, conversion of raw fuels, explosive combustion. Topics include laws of chemical equilibrium and heats of reaction; factors affecting reaction rates, catalysis; combustion stoichiometry, techniques of burning solid, liquid, and gaseous fuels; combustion equilibrium, explosive combustion, and detonation in engines; fuel situation, chemical conversion, new energy sources.

311. Instrumentation and Measurements. — ½ to ¾ unit; one one-hour period and one two-hour period a week; first semester. *Prerequisite:* Undergraduate courses in Mechanical Engineering Laboratory. Professor Konzo.

Instruments and measuring equipment for flow, temperature, pressure, speed, and gas analysis. Topics include theory and characteristics of a number of instruments used in research, development, and production; flow measurements of low pressure gases and liquids by Pitot tube, Thomas meter, orifices, nozzles, anemometers, Venturi meters, hot-wire anemometers, heated thermocouple anemometers, and displacement rotameters; temperature measurements by thermocouples, resistance thermometers, and pyrometers; hot-plate and hot-box conductivity meters; humidity and dew-point instruments, manometers; indicating and recording devices; special topics.

References: *Fluid Meters,* A.S.M.E.; *Temperature,* American Institute of Physics; Engineering Experiment Station bulletins; current literature.

314. Lubrication. — ½ to ¾ unit; two one-hour periods and one three-hour period a week; first semester. *Prerequisite:* Undergraduate courses in Machine Design and Fluid Mechanics.

The theories of lubrication; manufacture and properties of lubricants; methods of testing; lubrication methods and appliances. A study of the lubrication requirements of machines of many kinds. Topics include fluid friction and viscosity; boundary lubrication; thin film lubrication and oiliness; hydrodynamic theory of lubrication; extreme pressure lubricants; thermal equilibrium, bearing loads and design practices; ball, roller, and needle bearings; comparison of rolling-contact bearings with plain bearings.

Texts and references: *Theory of Lubrication,* Hersey; *Lubrication,* Norton; *The Theory of Film Lubrication,* Boswell; manufacturers' publications; current literature.

332. Theory of Internal Combustion Engines. — ½ to ¾ unit; three one-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Internal Combustion Engines. Associate Professor HULL.

Study of thermodynamics of reciprocating engine cycles, considering such factors as chemical dissociation, heat loss, combustion chamber shape, and flow through valves and manifolds. Topics include theoretical engine cycles and deviations of actual cycles from the theoretical; actual cycle analysis by computation and by chart; determination of heat loss during various stages of cycle; effects of compression ratio, manifold pressure, and exhaust pressure; study of valves, ports, manifolds, and mixture distribution, considering flow conditions.

Texts and references: *Internal Combustion Engines,* Taylor and Taylor; *Internal Combustion Engines,* Lichty; S.A.E. Transactions.

357. Industrial Safety. — ½ to ¾ unit; three one-hour periods a week; second semester. *Prerequisite:* Consent of instructor.

Detailed study of the principles of industrial (and related) accident prevention and their application. Course is designed to provide a sound working knowledge of safety principles for students interested in entering the field of safety engineering in industry. Topics include development of industrial safety movement including accident costs, accident sources and causes, and responsibility of management; appraising safety performance by safety inspection, job safety analysis, and accident investigation; planning and arranging for safety in production engineering; training, supervision, and organization; industrial hygiene; common hazards including explosions, fires, fumes, and electrical devices; special investigations.

Texts and references: *Industrial Accident Prevention,* Heinrich; American Standards Association Standard Safety Codes; Safe Practices Pamphlets, National Safety Council.

361. Railway Motive Power Equipment. — ½ to ¾ unit; two two-hour periods a week; first semester. *Prerequisite:* Senior standing in mechanical engineering. Professor SCHRADER.

A technical study of the various types of motive power used on railways with special emphasis on steam, Diesel, and electric locomotives, and secondary consideration to special types such as the steam turbine, turbo-electric, and gas turbine locomotives. Topics include primary considerations in design and locomotive ratios; economics, original costs, maintenance, availability, and effect on roadbed; general problems in design rather than of detailed parts; thermodynamics of various types, weight distribution,

and locomotive design ratios; legal considerations, Interstate Commerce rules and regulations; manufacturers' standards and specifications.

References: *The Steam Locomotive,* Johnson; A.A.R. Manuals; manufacturers' standards; current literature.

362. Railway Motive Power Operation. — ½ to ¾ unit; two two-hour periods a week; second semester. *Prerequisite:* Senior standing in mechanical engineering. Professor SCHRADER.

A study of the conditions under which railway motive power operates. Economics of operation, present equipment, proposed new equipment, servicing and maintenance, availability; train resistance, motive power tractive force, speed, time and distance curves, preparation of timetables; problems in stopping trains; terminal and repair facilities.

References: Engineering Experiment Station bulletins; current literature.

371. Petroleum Production Engineering — Field Development. — ½ to ¾ unit; three one-hour periods a week; first semester. *Prerequisite:* Senior standing. Professor LARSON.

Properties of petroleum, oil reservoirs, exploration and drilling methods, casing methods, and well logging.

Texts and references: *Petroleum Production Engineering-Development,* Uren; current literature.

372. Petroleum Production Engineering — Field Production and Exploitation. — ½ to ¾ unit; three one-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 371. Professor LARSON.

Study of reservoir performance, principle of oil and gas recovery, storage and transportation, and economics of oil field exploitation.

Texts and references: *Petroleum Production Engineering-Exploitation,* Uren; current literature.

Courses for Graduates

401. Thermodynamics. — 1 unit; three one-hour periods a week; first semester. *Prerequisite:* One year course in Thermodynamics. Professor ESPY.

Application of thermodynamics to the analysis and solution of engineering problems involving energy transfer and conversion. Topics include development of general thermodynamic equations and identities; development of modern methods for analysis of thermodynamic processes; methods of formulation and correlation of properties of working media from experimental data; thermodynamic analysis of flow of compressible media at high speeds.

Texts: *Thermodynamics,* Keenan; *Notes on Thermodynamics,* Goff.

402. Thermodynamics of Gaseous Equilibrium. — 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 401. Professor ESPY.

Application of thermodynamics to analysis of combustion of gases used as working media in power production. Topics include equilibrium as applied to problems of power production; chemical equilibrium as applied to

gaseous systems; calculations of equilibrium composition and temperatures; analysis of effect of equilibrium on internal combustion engine cycles; review of literature for application to power field.

Texts and references: *Thermodynamics,* Keenan; Engineering Experiment Station bulletins.

405. Heat Transfer. — 1 unit; two two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Heat Transfer. Professor LARSON.

Analysis of the methods and mechanisms of heat transfer, dimensional analysis method, design of heat exchangers, transient state heat transfer. Special problems in insulation and heat transfer. Topics include steady-state heat conduction, linear and two dimensional; Fourier's general equation; transient heat conduction; radiation exchange; radiation through and from gases; film theory; method of dimensional analysis; forced and natural convection equations; boiling liquids and condensing vapors; over-all heat transfer; fluid pressure losses.

Texts and references: *Heat Transmission,* McAdams; *Heat Transfer Notes,* Boelter and others.

408. Laboratory Investigations in Thermodynamics. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Thermodynamics and Mechanical Engineering Laboratory. Members of the staff.

Special investigations involving thermodynamic analysis, thermodynamic properties, and performances of physical and chemical systems. (See general notes on page 10.)

409. Laboratory Investigations in Fluid Flow, Heat Transfer, and Combustion. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Thermodynamics or Fluid Mechanics. Members of the staff.

Special investigations in flow, metering, heat transfer, heat exchanger design and performance, and combustion. (See general notes on page 10.)

413. Industrial Control Systems. — ½ unit; two two-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 311 or equivalent.

Study of basic elements of process control systems and process characteristics, particularly of thermal and mechanical processes. Topics include process characteristics including capacity, transfer, and dead time; measuring devices and their characteristics; automatic control devices which include single speed, proportional speed, and proportional position action with the application of reset and rate response to the latter.

Text: *Principles of Industrial Process Control,* Eckmann.

421. Heating and Air Conditioning. — 1 unit; two two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Heating, Ventilating, and Air Conditioning. Professor KONZO or Professor FELLOWS.

Advanced study of heating, ventilating, and air conditioning; factors affecting heat loss and heat gain of buildings, physiological effects of environment, equipment design of heat transfer equipment. Individual

problems. Topics include test methods and current research; climate in relation to health and comfort; structural components of buildings as related to heat gain, heat loss, solar orientation, and vapor transmission; human response to environment; ventilation requirements for health and safety; combustion and heat transfer including test methods for fuel burning devices, venting requirements, and heat transfer factors; heat transfer as applied to problems in the field.

Texts and references: Guide of A.S.H.V.E.; Engineering Experiment Station bulletins; current literature.

422. Heating and Air Conditioning Design. — 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 421. Professor KONZO or Professor FELLOWS.

Factors affecting design of steam, hot water, and air systems, including pipe and duct design, heat transfer rates, and control of equipment. Special topics such as panel heating, electrical heating, radiant heating, reverse cycle refrigeration. Topics include volume and temperature requirements, fan performance characteristics, resistance of fittings, and auxiliary equipment for air systems; flow through pipes, resistance of fittings, and pump characteristics for water systems; flow characteristics of steam systems; elements of automatic controls for heating and air conditioning.

Texts and references: Guide of A.S.H.V.E.; Engineering Experiment Station bulletins; current literature.

423. Refrigeration Theory and Application. — 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Undergraduate course in Refrigeration. Assistant Professor MARTIN.

Advanced study of processes and cycles; design problem; and special applications. Topics include thermodynamic aspects of compression cycles, properties of refrigerants, and performance calculations; air conditioning principles and psychrometric analysis of air mixtures; design of cold storage plant including heat gain, construction, selection of equipment, and plant layout; refrigeration processes including absorption, adsorption, stage compression, dual compression, dual refrigerants, steam jet, and centrifugal compression; term paper.

Texts and references: A.S.R.E. Data Book; A.S.R.E. Applications Volume; current literature.

428. Laboratory Investigations in Refrigeration. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate course in Refrigeration and Mechanical Engineering Laboratory. Assistant Professor MARTIN.

Special investigations in refrigeration. (See general notes on page 10.)

429. Laboratory Investigations in Heating and Air Conditioning. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Heating and Mechanical Engineering Laboratory. Members of the staff.

Special investigations in heating, ventilating, and air conditioning. (Note: Research projects sponsored by the Engineering Experiment Station include two or more heating research residences, as well as numerous

laboratory investigations. A limited number of students can be assigned to specific phases of these cooperative research projects. See general notes on page 10.)

431. Gas Turbines and Reaction Machines. — 1 unit; two two-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Thermodynamics, Power Plant Equipment, and Mechanical Engineering Laboratory. Professor LARSON.

Analysis of gas turbine cycles, media, combustion, construction and operation, impulse and reaction machinery; heat exchange and insulation. Topics include internal combustion gas turbine cycles; limitations and practicability; open cycle calculations; ideal and actual gases; compression ratios; regeneration; isothermal cycle; water injection; fuels and combustors; compressor and turbine blade dynamics and characteristics; cycle performance; closed cycles and special media; supercharging; structural and metallurgical problems.

Texts and references: Instructors' notes; *Jet Propulsion and Gas Turbines,* Zucrow; current literature.

438. Laboratory Investigations in Power Machinery. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate course in Mechanical Engineering Laboratory. Members of the staff.

Special investigations in power machinery, such as turbines, engines, fans, and compressors. In the operation of some of the equipment, two or more students may be required. (See general notes on page 10.)

441. Machine Design. — 1 unit; three two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Machine Design and Mechanics of Machinery. Professor RYAN.

A technical application course designed to focus the previously acquired design experiences on the creative problem of developing machines to perform specified functions; proper consideration of manufacturing processes involved; checking of all parts for stress, wear, vibration, fatigue, etc. Topics include new developments in strength of materials; application of manufacturing standards, study of lubrication methods, safety requirements, appearance, and costs; design of a machine that will involve investigation of specific problems to illustrate methods of analysis and development of their solutions.

Texts and references: *Machine Design,* Maleev; *Machine Design,* Leutwiler; engineering standards; manufacturer's publications; current literature.

442. Product Design. — 1 unit; three two-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Machine Design and Production Engineering.

A detailed analysis of the various constituent mechanisms and apparatus in power-driven machines designed for, or adapted to, special industrial operations such as those found in mass production. This analysis includes not only the machine itself and its mechanisms and auxiliary apparatus and attachments, but also such items as tools, jigs, fixtures, etc.

The material and final product studied with reference to the design or modification of new machines or apparatus, or the adaptability of existing machines or apparatus, to its production. Attention given to development of machines for mass production with particular reference to recent practice; effect of standardization and other factors that have influenced interchangeable manufacture and mass production.

Texts and references: *Production Engineering,* Buckingham; *Handbook on Design for Quantity Production,* Chase; manufacturers' publications; current literature.

443. Dynamics of Machinery. — 1 unit; two one-hour periods and one three-hour period a week; first semester. *Prerequisite:* Undergraduate courses in Machine Design and Mechanics of Machinery. Professor Ham.

A course complementary to the undergraduate course and devoted to a more detailed study of velocities, acceleration, and forces in machine parts having reciprocating, rotating, and combined motions; balancing, critical speeds, and vibrations in shafts; gyroscopic action in machines; flywheels, governors; special topics. Topics include graphical vs. analytical methods; velocity, acceleration, and inertia force diagrams; Coriolis' law and applications.

Texts and references: *Mechanics of Machinery,* Ham and Crane; current literature.

444. Analytical Design of High-Speed Engines. — 1 unit; two one-hour periods and one three-hour period a week; second semester. *Prerequisite:* Undergraduate courses in Machine Design and Mechanics of Machinery. Associate Professor Broghamer.

A study of the dynamics of high-speed engines with special reference to internal combustion engines, engine balance, crankshaft deflections, torsional vibrations. Topics include balancing of in-line, radial, and other types of engines; torsional vibrations in crankshafts and methods of damping; design analysis of crankshafts and crankshaft bearings; firing orders; analytical studies pertaining to design of cams, flywheels, and other parts; energy relations.

Texts and references: *Analytical Design of High-Speed Internal Combustion Engines,* Cousins; *Mechanics of Machinery,* Ham and Crane; *Aircraft Engine Design,* Liston; current literature.

445. Design of Internal Combustion Engines. — 1 unit; two three-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Mechanics of Machinery and Machine Design. Associate Professor Hull.

Detailed study of the design of the internal combustion engine; gas-pressure and inertia-force diagrams; determination of bearing loads; torsional vibration analysis; stress determinations and design of important parts, including piston, connecting rod, crankshaft, flywheel, valve mechanism and cam layout.

Texts and references: *Aircraft Engine Design,* Liston; current literature.

446. Power Plant Design. — 1 unit; three two-hour periods a week; second semester. *Prerequisite:* Undergraduate courses in Thermodynamics and Power Plant Design. Professor RYAN.

A design course covering the selection of equipment, and problems involved in the design and layout of a modern power plant. Topics include selection, performance characteristics, and integration of major and minor machinery in a steam power station; prevailing standards and procedures in power plant design.

Texts and references: *Notes on the Design of a Steam Power Station,* Leutwiler; manufacturers' bulletins; commercial standards; current literature.

448. Laboratory Investigation in Machine Design. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Machine Design and Mechanics of Machinery. Members of the staff.

Special investigations in machine design. Studies of some phase of mechanical transmission of power, including tests on belts, ropes, chains, gears, springs, clutches, couplings; wear and lubrication of bearings; vibration studies; static and dynamic balancing; force and stress analyses; photoelastic investigations. (See general notes on page 10.)

451. Materials Processing. — 1 unit; two two-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Metal Processing and Heat Treatment of Metals. Professor TRIGGER.

The theory and practice of metal cutting and forming. Survey of current technical literature and special topic assignments. Topics include forces and temperatures involved in drilling, milling, and single-point turning of materials; functions of coolants and lubricants in metal cutting; tool materials, performance characteristics, and factors involved in selection and application of tools; characteristics of work materials as related to processing.

Texts and references: *Metal Processing,* Boston; current literature.

453. Methods and Measurements of Industrial Work. — 1 unit; three one-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Motion and Time Study, and Production Control. Associate Professor LAITALA.

Advanced theoretical analysis of factors affecting determination of economical methods, method standards, and time standards for industrial operations. Special investigations and term paper. Topics include development of economical method, including product design, tools, working conditions, process used, and quality level; establishment of method standard; time measurements of industrial work including machine work and operator performance; standard data to be observed and analyzed; time standards for indirect type operations.

Texts and references: *Dynamics of Time Study,* Presgrave; *Time Study for Cost Control,* Carroll; current literature.

454. Production Engineering. — 1 unit; three one-hour periods a week; second semester. *Prerequisite:* Mechanical Engineering 453. Associate Professor LAITALA.

Advanced consideration of production engineering principles as related to cost analysis and reduction, control of flow of work in manufacture, evaluation of performance against standard and to compensation. Special investigations. Topics include structure of factory organization with emphasis on analyses and coordination of engineering functions; manufacturing costs as affected by sales forecast, standardization, tools and equipment used, engineering design, and alternate processes; estimating; evaluation of performance in terms of operator, the department, and the entire plant; materials control and scheduling of manufacturing operations, compensation of labor; application to departments other than production.

Texts and references: *Principles of Industrial Management,* Alford; current literature.

456. Measurement Standards. — ½ unit; three one-hour periods a week; first semester. *Prerequisite:* Undergraduate courses in Tool Engineering and Advanced Metal Processing.

Precision measurements in the field of production engineering, including interference phenomena of light, dimensional measurements, physical standards of reference, gauges, surface measurements, and theory of the profilometer.

458. Laboratory Investigations in Production. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Undergraduate courses in Metal Processing. Members of the staff.

Special investigations in field of production, particularly in materials, processing, and production engineering. (See general notes on page 10.)

468. Laboratory Investigations in Railway Mechanical Engineering. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Consent of instructor. Professor Schrader.

Special investigations in field of railway mechanical engineering. Note: Analysis or experimental research in the field of railway mechanical engineering, such as determinations of stresses in car wheels, problems in stopping trains, dynamics of traction and effect on rails, use of dynamometer car for testing train resistance and tractive effort. (See general notes on page 10.)

478. Laboratory Investigations in Petroleum Production Engineering. — ½ to 1½ units; one or more semesters; time to be arranged; first and second semesters. *Prerequisite:* Mechanical Engineering 371 or 372 or current registration. Professor Larson.

Special investigations in field of petroleum production engineering. Note: Studies of some phase of behavior and properties of fluids in porous media, recovery methods, well-drilling techniques, or storage and transportation of petroleum. (See general notes on page 10.)

491. Thesis. — 1 to 2 units; time to be arranged; first semester. *Prerequisite:* Completion of at least three units of graduate studies. Members of the staff.

Note: A thesis will be required of all candidates for the degree of Master of Science in Mechanical Engineering, except under unusual cir-

cumstances and with the consent of the adviser. Eight units, including a thesis, will be considered as the minimum number leading toward the fulfillment of requirements. If a thesis is not submitted, a minimum of nine units will be required.

A thesis will be required of all candidates for a degree of Doctor of Philosophy in Engineering.

The topic for the thesis will be selected by the student in consultation with a member of the staff. "Instructions for the Preparation of Theses" may be obtained at the office of the Graduate College.

492. Thesis. — 1 to 2 units; time to be arranged; second semester. (See note under course 491.)

493. Graduate Seminar. — No credit; one one-hour period a week; first and second semesters. *Prerequisite:* Graduate standing in mechanical engineering. Professor PARKER.

Presentation and discussion of significant developments in mechanical engineering. One semester required of all mechanical engineering majors. Note: Students should register during the last semester of their work leading towards the Master of Science degree. Students will present reports either of their research studies or of some phase of mechanical engineering reported in technical literature.

REGISTRATION DATES AND SUGGESTED PROCEDURE

Registration for the first semester normally is held during the third week of September, and that for the second semester during the first week of February. A graduate student in mechanical engineering may enter at either time. Commencement is held in June and February, but degrees are conferred also in August and October.

The following procedure is recommended for the prospective graduate student:

a. Secure a permit to enter the Graduate College from the Director of Admissions and Records.

b. Study the requirements for advanced degrees as given in this booklet and in the *Graduate College Announcement.*

c. Prepare a tentative outline of the sequence of courses to be taken.

d. Confer with the adviser, Professor N. A. Parker, Head of the Department of Mechanical Engineering, Mechanical Engineering Building, Urbana, Illinois.

Suggested Program of Graduate Study

The program of study is flexible and is designed to accommodate the interests of the individual. The courses listed below, which include certain courses offered by other departments, are suggestions from which a balanced program of study may be evolved. A balanced program should include offerings from all three of the following subdivisions: mathematical, theoretical and analytical, and technical or professional.

A candidate whose undergraduate credits do not include the prerequisite courses for any particular graduate study may be required to enroll without credit in such undergraduate courses at the University of Illinois.

Suggested Courses in the Three Major Subdivisions

Mathematical

Course Number	*Course Title*	*Unit Value*
Math. 341-342	Differential Equations	1 each
or Math. 343	Advanced Calculus	1
and Math. 345	Differential Equations and Orthogonal Functions	1
Math. 347-348	Introduction to Mathematical Analysis	1 each
Math. 368	Statistical Methods of Quality Control	1
Math. 387-388	Introduction to Applied Mathematics	1 each
T.A.M. 351-352	Engineering Analysis	1 each

Theoretical and Analytical

Course Number	*Course Title*	*Unit Value*
(1) M.E. 301	Engineering Thermodynamics	½ to ¾
M.E. 401	Thermodynamics	1
M.E. 402	Thermodynamics of Gaseous Equilibrium	1
Aero.E. 411	Advanced Aerodynamics of Compressible Fluids	1
Physics 360	Heat and Thermodynamics	1
Physics 362	Kinetic Theory of Heat and Radiation	1
(2) M.E. 303	Fuels and Combustion	½ to ¾
M.E. 314	Lubrication	½ to ¾
M.E. 405	Heat Transfer	1
T.A.M. 334	Fluid Mechanics and Advanced Hydraulics	½ to 1
T.A.M. 431	Fluid Mechanics	1
Ch.E. 371-373	Principles of Chemical Engineering	¾ each
Ch.E. 387	Flow of Fluids	¾
Ch.E. 388	Heat Transmission	¾
(3) M.E. 311	Instrumentation and Measurements	½ to ¾
M.E. 413	Industrial Control Systems	½
M.E. 456	Measurement Standards	½
E.E. 240-241	Electronics and Electronics Laboratory	½ each
E.E. 412	Advanced Engineering Measurements	1
E.E. 413	Servomechanisms and Automatic Control Devices	1
Physics 341-342	Electricity and Magnetism	1 each
Physics 343-344	Vacuum Tube Circuits	1 each
(4) M.E. 332	Theory of Internal Combustion Engines	½ to ¾
M.E. 431	Gas Turbines and Reaction Machines	1
M.E. 441	Machine Design	1
M.E. 443	Dynamics of Machinery	1
C.E. 461-462	Structural Theory and Design	1 to 2
T.A.M. 311-312	Advanced Dynamics and Vibrations	½ to 1
T.A.M. 421-422	Advanced Mechanics of Materials	½ to 1
T.A.M. 451-452	Theory of Elasticity	1 each
(5) M.E. 451	Materials Processing	1
Met.E. 208	Metallography and Heat Treatment	½
Met.E. 258	Alloy Steels	½
Met.E. 301	Metallurgy of Welding	½ to 1
Met.E. 302-304	Powder Metallurgy and Laboratory	½ to 1
Met.E. 305	Metallurgy of Steel Castings	½ to 1
Met.E. 306	Physics of Metals	½ to 1
Met.E. 403	Tool Steels and Related Alloys	1
Met.E. 404	Stainless Steels and High Temperature Alloys	1
T.A.M. 424	Properties of Materials	½ to 1

Technical, Professional, and Laboratory Investigations

Course Number	*Course Title*	*Unit Value*
(1) M.E. 408	Laboratory Investigations in Thermodynamics	½ to 1½
M.E. 409	Laboratory Investigations in Fluid Flow, Heat Transfer, and Combustion	½ to 1½
T.A.M. 493-494	Laboratory Investigations in Hydraulics	½ to 2
(2) M.E. 421-422	Heating and Air Conditioning	1 each
M.E. 423	Refrigeration Theory and Practice	1
M.E. 428	Laboratory Investigations in Refrigeration	½ to 1½
M.E. 429	Laboratory Investigations in Heating and Air Conditioning	½ to 1½
(3) M.E. 438	Laboratory Investigations in Power Machinery	½ to 1½
M.E. 442	Product Design	1
M.E. 444	Analytical Design of High-Speed Engines	1
M.E. 445	Design of Internal Combustion Engines	1
M.E. 446	Power Plant Design	1
M.E. 448	Laboratory Investigations in Machine Design	½ to 1½
T.A.M. 323	Advanced Laboratory Work in Testing of Materials	½ to 1
T.A.M. 493-494	Laboratory Investigations in Strength of Materials	½ to 1
(4) M.E. 357	Industrial Safety	½ to ¾
M.E. 453	Methods and Measurements of Industrial Work	1
M.E. 454	Production Engineering	1
M.E. 458	Laboratory Investigations in Production	½ to 1½
(5) M.E. 361	Railway Motive Power Equipment	½ to ¾
M.E. 362	Railway Motive Power Operation	½ to ¾
M.E. 468	Laboratory Investigations in Railway Mechanical Engineering	½ to 1½
(6) M.E. 371	Petroleum Production Engineering—Field Development	½ to ¾
M.E. 372	Petroleum Production Engineering—Field Production and Exploitation	½ to ¾
M.E. 478	Laboratory Investigation in Petroleum Production Engineering	½ to 1½
(7) M.E. 491-492	Thesis	1 to 2
M.E. 493	Graduate Seminar	0

Descriptions of all courses offered by the Graduate College are given in the *Graduate College Announcement,* which includes a large number of available courses not listed in the preceding pages. Courses to be offered during any specific semester are listed in the *Time Table* for that semester.